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13. ABSTRACT *(Maximum 200 words)*

An X-ray exposure tool has been completed, based on a commercially available stage system. All of the individual functions, including mask and wafer loading, coarse and fine alignment, and exposure, have been demonstrated. The development of a user friendly software package to control the sequence of operations is continuing. In addition, an interferometer has been developed which performs absolute distance measurements with nanometer resolution. By switching between several optical fibers a single such interferometer may be used to make accurate measurements along a multiplicity of axes.

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ALIGNMENT SYSTEM FOR ANORAD X-RAY EXPOSURE TOOL

FINAL PROGRESS REPORT

MARTIN FELDMAN

JANUARY 15, 1998

U. S. ARMY RESEARCH OFFICE

DAAH04-93-G-0411

LOUISIANA STATE UNIVERSITY

4 A STATEMENT OF THE PROBLEM STUDIED

For many years X-ray lithography has been the leading contender of new technologies for integrated circuit (IC) fabrication. Its throughput is far greater than that of e-beam lithography, and potentially is even greater than that of optical lithography. Moreover, resolution of 0.1 micron or better has already been well demonstrated, with wide process latitude and a very large depth of focus.

At present Silicon Valley Lithography Group is the only US supplier of X-ray step and repeat cameras, and tools only became available from them several years after this project was initiated. However, LSU had purchased an X-ray exposure tool from the Anorad Corporation, one of the world's leading suppliers of precision stage systems, and installed it on a soft X-ray beam line at their Center for Advanced Microstructures and Devices (CAMD) facility.

The principle purpose of this project was to upgrade the Anorad X-ray exposure tool by providing it with the ability to perform fine alignments between the mask and the wafer. This included:

1) Mechanical upgrades to the Anorad exposure tool to provide wafer rotation and the precise controlled motions required for fine alignment.

2) Implementation of a coarse alignment system based on a bright field video camera.

3) Implementation of a fine alignment system based on processing the images obtained with a high resolution, dual focus microscope with video readout.

4) Provision of a test bed for the development of future high precision fine alignment systems.

5) Interfacing the various subsystems with a user friendly control system.

A secondary purpose of this project was the development of a new kind of interferometer, capable of measuring absolute distances to nanometer accuracies. Such an interferometer would have many applications in the integrated circuit industry, in electron beam patterning tools as well as in optical and X-ray steppers.

B SUMMARY OF THE MOST IMPORTANT RESULTS

Mechanical Upgrades

A wafer rotation stage, and a fine alignment stage were developed by the Anorad Corporation, and successfully integrated into the Anorad exposure tool. Both stages are mounted directly behind the wafer chuck. The wafer rotation stage is a coarse stage with a total range of +/- 2 degrees, which is sufficient to correct any errors in wafer handling that may be made by the Genmark prealigner. After the rotation is performed the stage is vacuum locked to preclude any further motion.

The fine alignment stage, or "monolithic block," is a three degree of freedom precision stage machined from a single aluminum block. It was specially developed by Anorad for this purpose, and is believed to be unique both in its design and in its capabilities. Each of the three axes, X, Y_1, and Y_2, is driven by a pizeoelectric motor over a range of about 20 μm and the resulting motion is measured with a capacitance guage.. The two Y axes are 10 cm apart. They are either driven together, to provide translation in the Y direction, or they are driven in opposite directions to provide fine rotation. During acceptance tests with an interferometer, the absolute accuracy of the motion was found to be 5 nm (1 σ) over a range of +/- 10 μm in each direction.

Coarse Alignment System

A low magnification video microscope station has been constructed for coarse wafer alignment. Special search routines and a simulated joystick control allow the operator to quickly acquire the image of the wafer alignment marks and center them in the field of view. A single command then centers the wafer under the mask in the high magnification fine alignment position.

Fine Alignment System

A fine alignment system was implemented based on a long working distance dual focus video microscope. In this system images of the mask and wafer can be obtained either sequentially, or simultaneously, in orthogonally polarized light. The images are captured by a frame grabber, and analyzed to measure their relative alignment. The system worked well, and precisions of better than 30 nm (3σ) were readily obtained. Two very interesting results were obtained:

1) The alignment precision was the same with a conventional NTSC video camera as with a high resolution (Kodak Megaplus 1400) video camera. This is understandable, since even the NTSC camera had a pixel size 1/3 of the optical resolution. Nevertheless, it is a surprising result, implying that ther alignment algorithm is very efficient at extracting subpixel positional information.

2) The alignment precision was twice as good when the mask and wafer images were obtained simultaneously. This was anticipated and is a very important result - it implies that much of the error in conventional alignment systems arises from subresolution vibration which causes uncontrolled differences between the mask and wafer images.

Test Bed

A rigid optical table, suitable as a test bed for evaluating optical alignment systems, has been installed on the Anorad exposure tool. Although the present fine alignment system resides on this table more than one square foot of space is available for additional systems. One such system, based on linear zone plates and reported in the literature[1], has already been temporarily installed on the test bed.

Control Interface

A LABVIEW based control program is being implemented to operate the Anorad exposure tool. The program uses menus and representations of joysticks to guide the operator through each of the machine functions. Virtually all of the machine operations have been operated by the LABVIEW program. We are in the process of final debugging and consolidation of all the functions, including the image processing which is performed in a separate computer, into a single control system.

Interferometer

A new kind of interferometer has been developed by the Anvik Corporation. This interferometer measures the absolute distance between two mirrors, rather than changes in the distance. For convenience, a fiber optic guide is used to couple light from the main body of the interferometer to the two mirrors, which therefore may be mounted remotely. The measured accuracy is on the order of a nanometer, depending on the distance between the mirrors. The fact that absolute distances are measured has important consequences:

1) The interferometer light beam may be interrupted before a measurement is made. This is important to the operation of the Anorad X-ray tool, since during the hand-off procedure, when the mask is moved to the next exposure site, mirror alignment is lost and a conventional interferometer could not be used.

2) A single interferometer can be used with a multiplicity of remote heads, to measure distances along several axes. The ability of the interferometer to deliver light to a head through a fiber optic guide, and the availability of commercial fiber optic switches[2], make the task of multiplexing several heads with a single interferometer relatively straightforward.

C LIST OF ALL PUBLICATIONS

M. Feldman, L. Liu, S. Puduc, and C. Zhang, "Performance Characteristics of a Dual Focus X-Ray Alignment Microscope," *J. Vac. Sci. Technol.*, vol. B-13, no. 6, pp. 2660-2664, November/December 1995.

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M. Feldman, "Demountable Epoxy Joints," *R. Sci. Instru.*, June, 1997.

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5 REPORT OF INVENTIONS

Dual Focus X-Ray Alignment Microscope

Transporter for Optical Spectrum Analyzer in Alignment System

Absolute Distance Measuring Interferometry Using Multi-Pass Resonant Cavity Referenced to a Stabilized Laser Source,

6 BIBLIOGRAPHY

1) H. Zhou, M. Feldman, and R. Bass, "Subnanometer alignment system for x-ray lithography," *J. Vac. Sci. Tech*, vol. B 12(6), pp. 3261-3264, Nov./Dec. 1994.

2) Available for example from E-Tek Dynamics, Inc., 1885 Lundy Ave, San Jose, CA 95131.

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Sincerely,

Martin Feldman
Professor

Enclosure 4